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Characteristics of Fireline Blasted With Linear Explosives: Initial Test Results

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ABSTRACT

Based on limited data, water-gel provided a slightly wider and deeper fireline with more feathering of ejected material than did Ensign-Bickford cord. Soil moisture conditions, closeness of blasting material to the ground, and other factors may explain these differences.

KEYWORDS: fireline, blasting, linear explosives, water-gel, fireline cord, fireline construction

Fireline performance and construction are continually of interest to personnel engaged in wildfire suppression and fire use. Throughout the years, numerous techniques for fireline construction have been tested, evaluated, and used. Some provided real improvements in wildfire suppression; others were merely tried and rejected for failure to meet an array of evaluation criteria. Today, with increased costs for equipment and labor, and fewer fire suppression personnel available for duty, alternative methods of fireline construction are in demand. Fireline requirements for prescribed burns add a whole new array of needs and associated problems.

Explosives have for many years been considered a possible tool for wildfire fireline construction. In 1947 Johnson described use of Army explosives as a potential aid to fire suppression personnel. Ten years later, Banks and Fenton (1957) discussed use of Primacord[2] for blasting fireline. Since those early works, which indicated possibilities for operational use, fireline construction with explosives has been an on-again, off-again proposition. Explosives in linear form were found to produce fireline which was as good as, and sometimes superior to, fireline constructed using more traditional methods. In the mid-1970's the USDA Forest Service Equipment Development Center in Missoula, MT (MEDC) reviewed fireline explosives, developed nonincendiary explosive cord, and evaluated applications. Lott (1977, revised) discussed at length fireline explosive use and procurement instructions. Subsequently, another type of explosive, water-gel, also in a linear configuration, was evaluated and described by Ramberg (1978).

Since that time scattered work has been done in fireline explosive evaluation and development. Although one type of linear explosive has been approved for building wildfire fireline, its use has been limited in many areas. This explosive is the seven-strand Ensign-Bickford fireline cord. With an increase in the number of personnel trained to use explosives, fireline construction with explosives is becoming more widespread.

Unfortunately, explosives are being used without benefit of adequate guidelines or cost figures to help managers make sound decisions and allocations. The need for more detailed information and further evaluation of explosive techniques is evident. Such determinations have been made in the past, but the information was either local in nature or limited in depth, and not widely available to other users.

The British Columbia Forest Service (1972) provided quantitative measures of fireline constructed with linear explosives. These tests showed fireline could be blasted up to 16-inch widths, depending upon type of explosive and method of deployment. Little published information describes the quality of finished fireline constructed with linear explosives. To compare fireline built with explosives to that built by other construction methods, such as hand crews or bulldozers, it is necessary to have common measurements and criteria with which to make sound cost comparisons. This information is necessary not only for an evaluation of economic considerations of fireline construction using different methods,

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but also to provide the basis by which simulations could be made using several methods for various forms and levels of planning. Therefore, a study was begun to determine physical characteristics of fireline constructed with linear explosives. Initial results are given here.

METHODS

Sites were chosen west of Missoula on the Nine Mile Ranger District of the Lolo National Forest and in the University of Montana's, Lubrecht Experimental Forest, about 25 miles (40 km) east of Missoula. The sites included representative ground fuels and cover types important in western Montana. The sites were predominantly Douglas-fir on a southerly exposure, lodgepole pine, and clearcut units. We selected three general classes of ground cover as providing a range of conditions for our initial evaluation process—open grass, moderate fuels of down and woody materials in addition to some brush, and a heavy fuel situation where considerable down and dead material was present along with heavy brush.

Figures 1, 2, and 3 show examples of the cover types where blasting tests were carried out. Figure 1 represents fuel model 10, figure 2 represents fuel model 8, and figure 3 represents fuel model 2 (Anderson 1982). At each site, certain preblast material was inventoried. Permanent stakes were placed in the ground to reestablish the same sample points following blasts so that material removed from the area could be accurately measured.

Most available linear explosives come in 100-foot (30.5-m) lengths; therefore, one 100-foot transect was laid out at each test site with twenty sampling points at 5-foot (1.5-m) intervals along each transect. The transects were oriented to cover representative parts of each site. Data were recorded at each of the points both before and after blasting. The measurements of primary interest were width of fireline mineral soil after blasting, average depth of the fireline, and average width of ejected material on either side of the fireline (fig. 4).

Figure 1.—Heavy cover type (fuel model 10).

Data also were recorded for vegetation removed, type of ground, and size of material encountered. These factors were considered important by Ramberg (1978) and Lott (1977). The two explosives used in this study were Ensign-Bickford fireline explosive cord (7 strand) and IRECO's "Iremite 60" water-gel. These will be referred to throughout the paper as Ensign-Bickford cord and water-gel.

Figure 2.—Medium cover type (fuel model 8).

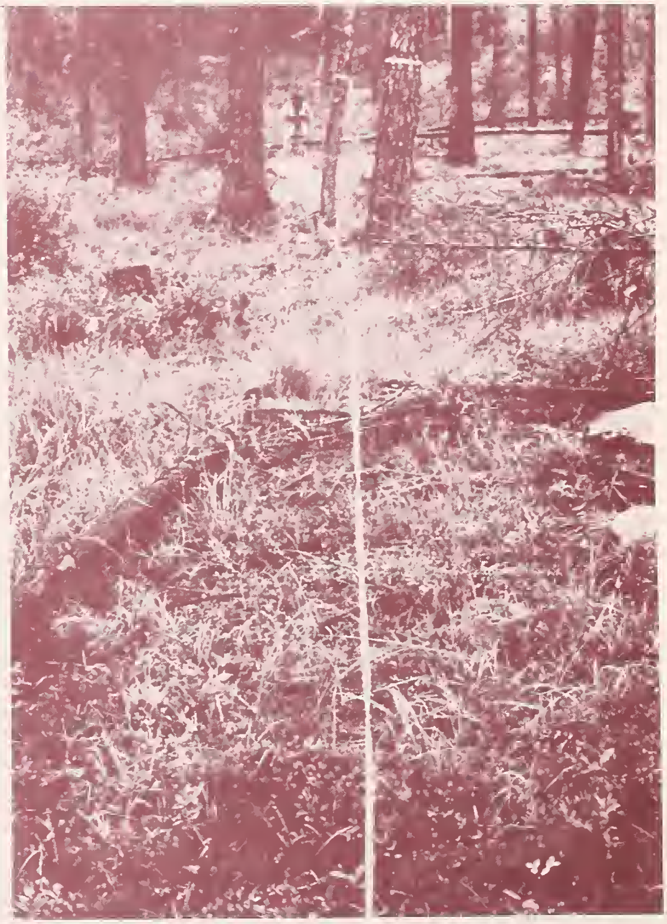

Figure 3.—Light cover type (fuel model 2).

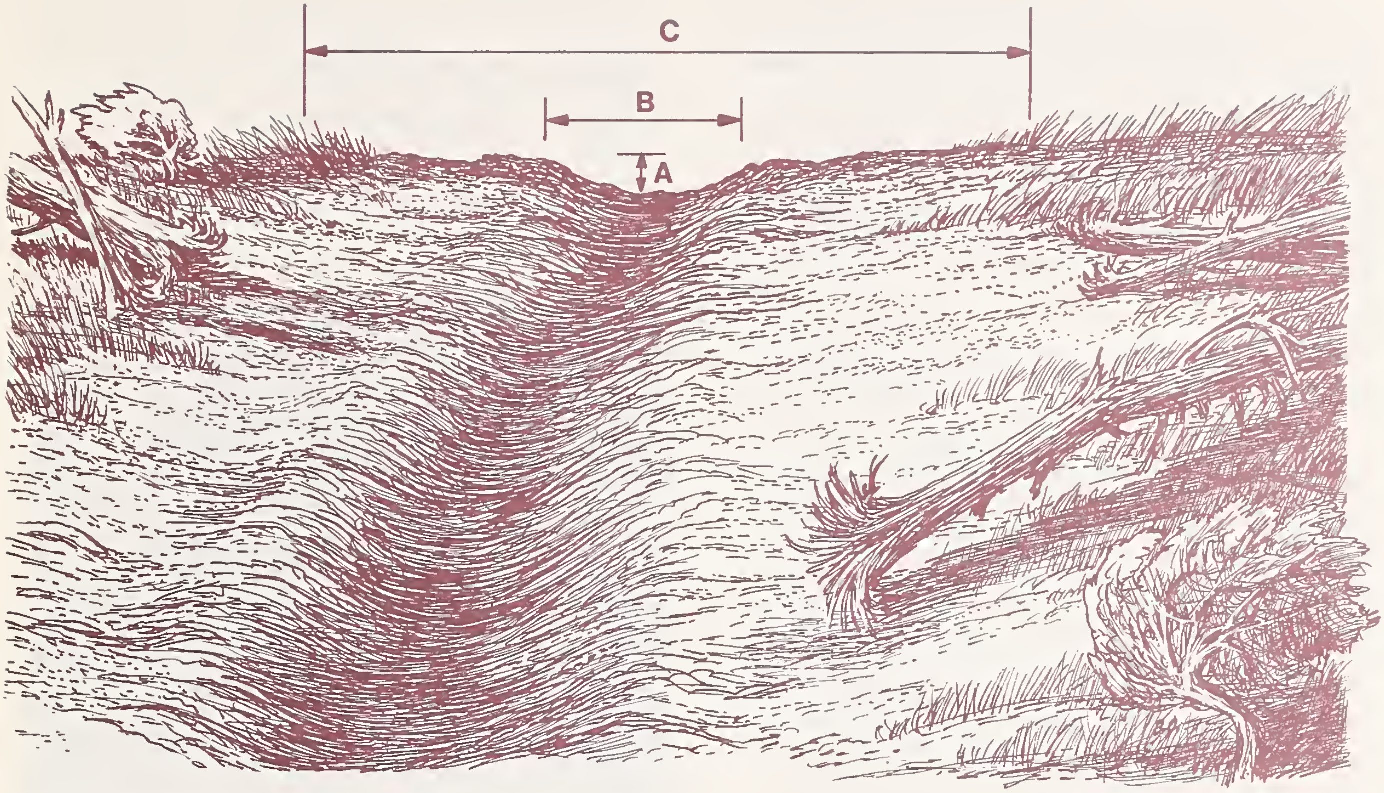

Figure 4.—Measurements of primary interest in the linear explosives study: ***A****, fireline depth;* ***B****, fireline width;* ***C****, width of ejected material.*

Table 1.—Number, means, and standard deviations for measurements taken of fireline blaster with two types of linear explosive in four fuel types

		Ensign-Bickford					
		Width		Depth		Feather	
Fuel	N	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
		Inches				Feet	
Light	36	17.22	5.70	2.36	0.76	8.04	2.92
Medium	36	11.25	9.39	1.56	1.42	10.79	5.89
Heavy	[1]36	13.33	5.66	3.61	1.46	8.67	2.25
Combined	[2]108	14.06	8.85	2.51	1.51	9.17	4.15
		Water-gel					
		Width		Depth		Feather	
Fuel	N	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
		Inches				Feet	
Light	126	16.10	5.87	2.40	1.32	10.57	2.95
Medium	90	17.19	6.30	2.61	1.10	10.57	4.22
Heavy	54	17.11	4.72	3.5	1.00	12.24	3.59
Combined	270	16.67	5.81	2.69	1.26	10.88	3.63

N = number of observations
$\bar{X}$ = mean value
SD = standard deviation

[1]N = 18 for Ensign-Bickford width only.
[2]N = 90 for Ensign-Bickford width only.

Normal operating procedures and safety practices detailed in the Blaster's Handbook (USDA 1980) were observed in all blasting operations. The tests were made by smokejumpers from the Missoula Aerial Fire Depot and Montana State Forestry personnel in conjunction with blasting training exercises. At least three blasts of each type of explosive were made on each approved date. Appendix I is the field data collection form; appendix II is the instructions issued for completing the form.

ANALYSIS

Data from field forms (appendix I) were entered into the computer at the Northern Forest Fire Laboratory for analysis.

Table 1 shows means and standard deviations for the basic measurements taken. The average width of the fireline in each cover type, the average depth blasted into the mineral soil, and the average width of the ejected material or feathering (dusting effect) are indicated. Many people who have used fireline cord, especially in prescribed burning activities, believe that ejected soil (the feathering effect) created by blasting adds an additional 6 to 12 feet (1.8 to 3.7 m) or more of effective fireline if the line is blasted shortly before ignition. The ejected moist soil has a retarding effect on the combustion process slowing down the rate of spread and diminishing fire intensity. Ejected material also has a retarding effect when the soil is drier or after some time; however, it is most effective immediately after blast when the soil is usually dampest. Dust coatings on fuels adjacent to forest roads and trails are commonly known to slow or stop fires.

We also noted that in many cases some minor fireline cleanup work had to be done to at least break the bridging of downed logs or limbwood that was not blasted away. Some advocates of fireline blasting indicate that sawing before blasting is most appropriate and less hard on saw chains; however, much material is often blasted out of the way and a crew need only saw what remains after the explosion.

DISCUSSION AND CONCLUSIONS

There is no question that the 100-foot (30.5-m) segments of blasted line, after cleanup, should be effective firebreaks. Figures 5 and 6 show before and after views of a blasted line in fuel model 2. The utility of blasting must next be coupled with the cost of the material used and the total cost of putting it on the ground and blasting. This then can be compared with production rates of crews or bulldozers in similar situations to determine which is the most cost-effective technique.

Data in table 1 suggest a slight statistical difference in performance characteristics between the two types of linear explosives used in our test. Line width blasted to mineral soil was on the average slightly greater using water-gel than the Ensign-Bickford cord. It is difficult to determine specifically why this occurred; however, one factor seems to be that the water-gel will lie closer to the ground. The material is much more pliable than the Ensign-Bickford cord and conforms to the irregularities of the ground more easily. Water-gel has more total explosive per unit length; however, Ensign-Bickford cord has more retardant to prevent fires from being ignited. Soil moisture content may also have played an important role, but we did not find any significant relationships between soil moisture and line width. This was evaluated for both explosive types and each fuel type as well as with all data combined. Trends are

Figure 5.—Light cover type (fuel model 2) before blasting.

Figure 6.—Light cover type (fuel model 2) after blasting.

indicated, but they are not supported well enough by our limited data base to provide definitive answers.

Line depth created by either explosive was similar, regardless of fuel. No strong relationships were found between soil moisture and line depth. However, data did lend some support to the assumption that increased soil moisture would produce deeper line. The British Columbia studies produced this type of result. Additional samples could improve our information base and possibly indicate stronger relationships between depth of blasted line and soil moisture content.

Although line width varied, the average width of feathering for both types of explosives was similar. Regression analysis of soil moisture and width of ejected material showed weak relationships. Some plotted data showed a relationship; however, the limited amount and range of data preclude any definitive conclusions.

Any brush that was over or near the blast area was totally removed or the leaves were stripped from the branches. In several relatively thick alder patches branches were stripped clean of leaves and branches within about a foot of the cord were blown away. Many of the roots were also severed.

Rotten material, including logs and stumps, was especially susceptible to removal by blasting. The blast blows away much of this material or breaks it up so completely that it can be kicked aside or completely removed with minor shovel work.

Sound logs about 4 inches (10 cm) or less in diameter usually were broken by the blast unless the log had been positioned a foot or more above the cord before blasting. Materials larger than 4 to 6 inches (10 to 15 cm) in diameter were very seldom blasted apart or removed unless they had been positioned directly on top of the cord. If the cord was placed on top of a larger log, the log was almost never blasted totally apart. However, larger logs could be blown apart if they were wrapped with explosive. Considerable material was eroded from large logs that were not broken; the amount depended on log soundness and whether they were located above or below the explosive. If we wrapped the log with the main line or a short strip of explosive, it could usually be easily severed.

Contrary to some opinions, neither type of explosive would blow a clean line if it was merely laid along the ground and placed over or under logs. Some material had to be removed after the blast. However, only minimal effort was needed to clean up the line. It was the consensus of those involved with each blast that line cleanup would require little additional effort by one or two persons.

A three- to six-person crew can build a lot of fireline in a day with explosives, far in excess of what a 20-person crew could produce with handtools. Therefore, there are applications in wildfire control and prescribed fire that must be considered where labor is not available or where time is severely limited.

FUTURE RESEARCH

Our results indicate some initial responses in some cover types to fireline blasting. We are in the process of making tests in several other cover types. When this phase is done, we will have extensive data on characteristics of line built in various cover types and should be able to define any areas where blasting is not productive. We then plan to develop cost-per-unit data for blasting in field operations.

Some of our observations made on fireline blasting were parallel to those made by MEDC personnel in earlier reports. One that we believe has much promise is that fireline created by linear explosives has a tendency to revegetate at a much more rapid rate than does fireline built conventionally with handtools. This will be reported on following another field season. If, indeed, subsequent study supports our initial observations, environmental quality considerations may be a major factor in offsetting the cost of explosives.

Blasting fireline has a place in the continually improving fireline construction tool box. Specific data on general costs, cost per unit, environmental considerations, benefits, and other factors are needed to determine the true utility of this method. Changing budgets, management requirements, and manpower availability all have a role in determining the amount and extent of use of fireline blasting, in both fire suppression and prescribed burning. Knowing the physical characteristics of blasted line is an important piece of a large picture. Such information will support the more appropriate application of this emerging technology.

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APPENDIX I
FIRELINE EXPLOSIVE STUDY

Field Data Collection Form

I. Explosive type
Ensign-Bickford or water-gel ________

II. Identification
1. Date ________ __ __ __ __ __ __
2. Time hours ________ __ __ __ __
3. USFS Region ________
4. Forest ________
5. Ranger District ________
6. Scheduled test no. ________ __ __
7. Wildfire name ________
8. Prescription fire name ________
9. Observer ________

III. Environmental conditions
1. Air temperature ________ __ __ __
2. Relative humidity ________ __ __
3. Percent slope ________ __ __
4. Aspect ________ __ __
5. Soil type ________ __
6. Soil moisture __ __

IV. Fuel information
1. Fuel type and cover ________ __
2. Fuel model ________ __ __

V. Preblast data
1. Location of measurement ________ __ __
2. Litter layer ________ __ __ __
3. Duff layer ________ __ __ __
4. Grass height ________ __ __ __
5. Grass - percent ground coverage ________ __ __ __
6. Brush cover - percent ________ __ __
7. Number of brush intercepts: 0-¼ ________ __ __
(by size class) ¼-½ ________ __ __
½+ ________ __ __
8. Brush foliage condition ________ __
9. No. of log intercepts: 3"-6" ________ __ __
6"-12" ________ __ __
12"+ ________ __ __

VI. Postblast data
1. Location of measurement ________ __ __
2. Width of blasted line to mineral soil ________ __ __
3. Width of ejected material ________ __ __ __
4. Depth of blasted line ________ __ __
5. No. of root intercepts: 0-¼ ________ __ __
(by size class) ¼-½ ________ __ __
½+ ________ __ __
6. No. of brush intercepts: 0-¼ ________ __ __
(by size class) ¼-½ ________ __ __
½+ ________ __ __
7. Percent brush defoliation ________ __ __
8. Number of log intercepts: 3"-6" ________ __ __ __
6"-12" ________ __ __ __
12"+ ________ __ __ __

VII. Remarks:

APPENDIX II
INSTRUCTIONS FOR PREPARATION AND CODING OF FIRELINE EXPLOSIVES STUDY

Field Data Collection Form

General. One form will be prepared for each observation made. All applicable blanks will be filled in on the left-hand side of the form at the time of each observation. A new form will be used at each designated measurement point in the explosive line in scheduled tests. Observations and measurements on wildfires and prescription fires will be made to the extent time and fire conditions permit. Coding of forms may be completed later.

I. Explosive type. Check correct blank and code 1 for Ensign-Bickford and 2 for water-gel.

II. Identification

1. Date. The date will be entered and coded; August 8, 1982, would be 080882.
2. Time. Use a 24-hour clock. 2:30 p.m. is 1430. When coding, enter only to the nearest hour; i.e., 1335 would be 1400; 1325 would be 1300.
3. USFS Region. Enter number of Region—1, 4, 6, etc.
4. Forest. Enter name of Forest.
5. Ranger District. Enter name of District.
6. Scheduled test number. Enter number of test. Code direct—1 = 01; 11 = 11; etc.
7. Wildfire name. Enter fire name.
8. Prescription fire name. Enter prescription fire name or other identifying term.
9. Observer. Enter observer's name.

III. Environmental conditions

1. Air temperature. Enter as degrees Fahrenheit. Code direct—45 = 45, etc.
2. Relative humidity. Enter as percent. Code direct—25% = 25, etc.
3. Percent slope. Enter the percent slope in the direction of line construction. Code 5% as 05; 99% and above are coded 99.
4. Aspect. Enter as direction; i.e., north, northwest, south, etc. for eight compass points. Code north as 01 and proceed clockwise on compass to northwest as 08.
5. Soil type. Enter and code as follows:

Sandy	1
Clay	2
Loam	3
Gravel	4
Light rocky (occasional rocks)	5
Medium rocky (10-50% rocks)	6
Heavy rocky (51-75% rocks)	7
Rocky (75%+ rocks)	8
Peat or heavy organic	9

6. Soil moisture. Enter as percent. Code direct—5% = 05; 15% = 15, etc. Soil moisture will be determined in the lab.

IV. Fuel information

1. Fuel type and cover. Record and code as follows:

Light - grass with forbs	1
Medium - open pine stands	2
Medium-heavy - brush predominating	3
Heavy - dense conifer stand	4
Extreme - clearcut slash	5

2. Fuel model. Enter the NFDRS fuel model appropriate for the area; i.e., model A = 1; model E = 5, etc.

V. Preblast data

1. Location of measurement. Enter as feet from ignition end of explosive line. Code direct—5 feet = 05, etc.
2. Litter layer. Enter as depth in inches to nearest ¼ inch. Code direct—2 inches = 200; 4¾ inches = 474, etc.
3. Duff layer. Enter as depth in inches to nearest ¼ inch. Code direct—2 inches = 200; 4¾ inches = 475, etc.

(con.)

4. Grass height. Enter in inches to nearest ½ inch. Code direct—2 inches = 020; 3½ inches = 035, etc.
5. Grass—percent ground cover. Enter as visual estimate to nearest 10%. Code direct—10% = 10, etc.
6. Brush cover percent. Visual estimate to nearest 10%. Code direct—10% = 10, etc.
7. Number of brush intercepts. Enter as total number by size class. Code direct—11 intercepts = 11, etc.
8. Brush foliage condition. Enter and code as follows:

Green	1
Cured	2
Shed	3

9. Number of log intercepts. Enter and code as follows (number of log intercepts measured from last point to current measurement point): 01 = 1 intercept; 05 = 5 intercepts, etc.

VI. Postblast data

1. Location of measurement. Enter as feet from ignition end of line. Code direct—5 feet = 05; 15 feet = 15, etc.
2. Width of blasted line to mineral soil. Enter as inches to nearest inch. Code direct—3 inches = 03, etc.
3. Width of ejected material. Enter to nearest foot. Code direct—1 feet = 015; 15 feet = 150, etc.
4. Depth of blasted line. Enter to nearest inch. Code direct—1 inch = 01, etc.
5. Number of root intercepts. Enter as total number by size class. Code direct—10 intercepts = 10, etc.
6. Number of brush intercepts. Enter total number of intercepts by size class. Code direct—5 intercepts = 05; 11 = 11, etc.
7. Brush defoliation. Enter ocular estimate to nearest 10%. Code direct—10% = 10, etc.
8. Number of log intercepts. Enter and code as follows: 01 = 1 intercept; 05 = 5 intercepts, etc.

VII. Remarks. Enter any pertinent information not specifically called for in instructions—such items as incomplete detonation of explosives, aborted test, etc.

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